Potential Output and the Recent Productivity Decline

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POTENTIAL output refers to the real gross national product (GNP) that is produced if the economy operates under high-employment conditions. Measures of potential output depend on measures of available resources, such as capital and labor, and reliable estimates of the relationship between national output and the employment of resources.

Since 1973, the growth of productivity (measured as output per unit of labor) has slowed substantially (see chart 1), raising doubt about the relationship of input to output and, therefore, the measurement of the nation's potential GNP. This issue is of considerable importance as it bears on the traditional concern over the degree of resource underutilization and the associated output losses in the economy. An accurate assessment of potential output is essential to determine the expected gain in output from a policy intended to achieve full employment. The relationship between resource supplies and potential output also is important in analyzing the output gain from supply-side policies to increase the supply of resources through increased work, saving and investment.

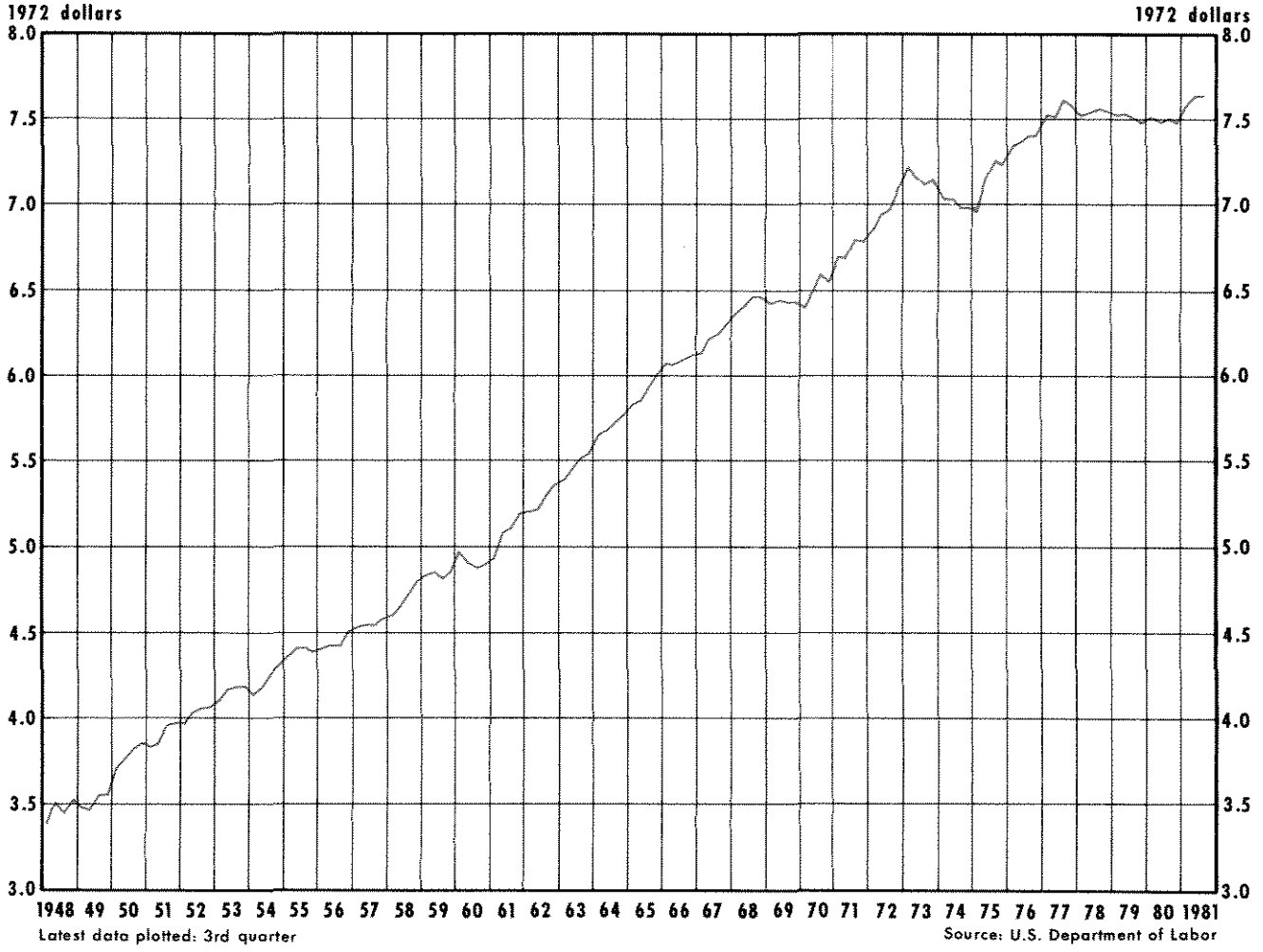
This Bank's measure of potential output differs from others in that it provides direct estimates of the effects of labor force growth, capital accumulation *and* changes in the relative cost of energy resources on productivity and economic capacity.[1] The stability of the input-output relationship on which this measure is based, and its ability to fully account for the unusual productivity developments during the last decade, provided support for the credibility of past estimates. Since energy costs have increased dramatically since 1978, it is important to verify that the earlier empirical results are consistent with recent productivity experience, as well as to assess the impact of this shock on potential GNP. Also, recent revisions of the GNP accounts incorporate new information on output and involve some conceptual changes that require revisions in potential GNP measures. In addition, since 1977 some modifications have occurred in the methods used by this Bank to measure potential output. The revisions and modifications are described below.

ENERGY PRICE SHOCKS AND PRODUCTIVITY

A sharp increase in the relative price of energy causes a reduction in the output (productivity) of existing labor and capital resources, or economic capacity. The particular channels through which this change occurs vary from firm to firm, but include changing production methods to reduce the use of higher-cost energy, the closing of plants rendered unprofitable, reduced optimal and actual use of existing facilities, and the diversion of labor and capital resources to uses that economize on higher-cost energy. These changes result in less output being produced despite an initially unchanged availability of domestic capital and labor resources. As a result, measures of productivity such as output per worker, per hour, or per unit of capital, decline. The rise in energy prices also induces a percentage increase in the nominal prices of output equal to the percentage decline in productivity or potential out-

[1]The original measures used by this Bank and the methods of their construction are explained in Robert H. Rasche and John A. Tatom, "Energy Resources and Potential GNP," this *Review* (June 1977), pp. 10-24. The theoretical basis for the energy price effect is developed in Robert H. Rasche and John A. Tatom, "The Effects of the New Energy Regime on Economic Capacity Production and Prices," this *Review* (May 1977), pp. 2-12. These hypotheses are further elaborated, and international evidence supporting them are presented in Rasche and Tatom, "Energy Price Shocks, Aggregate Supply and Monetary Policy: The Theory and International Evidence," in Karl Brunner and Allan H. Meltzer, eds., *Supply Shocks, Incentives and National Wealth*, Carnegie-Rochester Conference Series on Public Policy, Vol. 14 (1981), pp. 9-93.

Chart 1
Output per Hour (Private Business Sector)



put, since less output is producible for a given supply of money.

In addition, the decline in productivity shifts the demand for labor and capital resources down. In the short run, these shifts are reflected in a fall in the real wages of workers and a decline in the value of existing plant and equipment relative to its replacement cost. Over a longer period, the capital stock available per worker will decline from the level that would otherwise have occurred, so that the long-run decline in potential output, labor productivity and real wages is larger than the initial decline.

The effect of a rise in the relative price of energy on production is manifested in a production function approach through reductions in inputs (especially reduced energy usage), or through changes in productive efficiency or capacity that are "disembodied," that is, not associated with changes in the use of physical inputs such as labor, capital or energy. Earlier studies have provided an unbiased estimate of the effect of a rise in the relative price of energy on output that supports the energy price/economic capacity hypothesis.[2] Before re-examining

[2]An elaborate review of other analyses of energy price effects on the economy is presented in Rasche and Tatom, "Energy Price Shocks, Aggregate Supply," pp. 16-33. A more recent critique of the analysis here is Ernst R. Berndt, "Energy Price Increases and the Productivity Slowdown in United States Manufacturing," Federal Reserve Bank of Boston, *The Decline in Productivity Growth*, Conference Series No. 22 (June 1980), pp. 60-89.

Berndt finds no effect of higher energy prices on manufacturing productivity, in contrast to the evidence in John A. Tatom,

the production function estimates, however, it is useful to review recent revisions in the data series used to estimate potential GNP.

THE RECENT GNP AND CAPITAL STOCK REVISIONS

From time to time, the U.S. Department of Commerce announces major revisions in the GNP accounts based on new source data, new estimating procedures and definitional or conceptual changes. The latest revision was published in December 1980.[3]

The basis of the recent revision was new information from the 1972 input-output tables, the 1977 economic censuses of various industries, and information from the 1973 and 1976 Taxpayer Compliance Measurement Program. In addition, GNP was redefined to include the reinvested earnings of incorporated foreign affiliates of U.S. direct investors and to exclude those of incorporated U.S. affiliates of foreign direct investors. The redefinition of GNP primarily affects the measure of income originating in the rest of the world, with little effect of the measurement of output from the nation's private sector.

Another important part of the revision was in gross private domestic investment. The revision of this measure was largely due to revised estimates of producer durable equipment investment. At the same time, a conceptual change occurred, shifting the output and investment in hotels and motels from the residential to the nonresidential sector. Except for the treatment of reinvested earnings abroad, however, the revisions of GNP primarily affect data beginning in 1968.

Table 1

Revisions in Real Net Capital Stock and Private Business Sector Output (selected years)[1]

Year	Upward revision of capital stock at beginning of year	Upward revision of private business sector output
1950	2.1%	0.3%
1955	2.0	0.6
1960	1.8	0.5
1965	2.9	0.2
1970	2.9	0.2
1975	4.9	2.8

[1]Figures are the percentage increase of 1980 revised data over data available in 1977.

The new source information affected measures of the nation's capital stock as well, especially after 1967. The reclassification of hotel and motel capital stocks is the primary source of changes in the measures prior to 1967. While the level of the nation's net nonresidential private capital stock (constant prices) was raised because of these changes, the growth rate was changed very little prior to 1973. For example, the revised data show a 4.2 percent annual rate of growth from 1948 to 1968, the same as earlier data. From 1968 to 1973, the revised data indicate growth of the net capital stock at a 4.4 percent rate, up from 4.0 percent in the earlier data. From 1973 to 1978, the revised capital stock shows that capital formation slowed to a 3.1 percent rate. Earlier data show the same extent of slowing in capital formation to a 2.7 percent rate from 1973 to 1978. As a result, the conclusion of earlier research that capital formation slowed subsequent to 1973, especially when measured relative to labor force growth, has been unaffected by the revisions. The rate of growth of the capital stock, however, has been somewhat faster since 1968 than earlier estimates showed; this could affect earlier estimates of input-output relationships.

Table 1 shows the extent of both the upward revision of the constant-dollar net stock of fixed nonresidential private capital at the beginning of the year and the private business sector output for data used in 1977 as compared with the recent revisions. The capital stock has been revised upward relatively more than output.

"The Productivity Problem," this *Review* (September 1979), pp. 13-14. Unfortunately, as Berndt notes, a major share of energy resources is classified as raw materials in his data set, and his analysis can be easily extended to show that most of the productivity decline he analyzes is due to an increase in the relative price of these "raw materials." Berndt also claims to show that an observed decline in the value of claims on existing physical capital relative to the replacement cost, as hypothesized above, is also not explained by energy price increases. His theoretical analysis is flawed by the omission of a significant output effect that substantially raises the magnitude of his estimate of the effect of higher energy prices on the value of existing capital.

[3]For a discussion of these revisions, see Keith M. Carlson, "Recent Revisions of GNP," this *Review* (March 1981), pp. 27-32; and "The National Income and Product Accounts of the United States: An Introduction to the Revised Estimates for 1929-80," *Survey of Current Business* (December 1980), pp. 1-26.

THE PRODUCTION FUNCTION

The basis of this Bank's potential output estimates is a production function for private business sector (PBS) output that relates output to hours of employment, the utilization of capital, and energy. Available measures of energy tend to be broken down by types of users, such as residential, commercial and industrial. No energy measures exist that are detailed by production vs. consumption use by households, or by producing sectors like the manufacturing and private business sector. Since energy measures compatible with existing data on sectoral output and employment of labor and capital do not exist, a "first-order condition" for energy employment is used to eliminate the quantity of energy from the production function, replacing it with the relative price of energy. Formally, the estimated equation is of the form,

$$(1)\quad \ln X_t = \beta_0 + \beta_1 \ln h_t + \beta_2 \ln k_t + \beta_3 \ln (Pe/P)_t + \beta_4 \ln t,$$

where X_t is PBS output in period t, h_t is hours of all persons, k_t is the utilized net nonresidential capital stock (constant prices), the product of the Federal Reserve Board manufacturing capacity utilization rate and the capital stock in place at the end of period t-1, and Pe/P is the relative price of energy, found by deflating the producer price index for fuel, power and related products by the implicit price deflator for private business sector output. The t term is a time trend intended to capture the rate of technology change. When equation 1 is derived from a Cobb-Douglas production function, the βs in equation 1 are related to the output elasticities of the inputs, as shown in table 2.

Estimates of the annual production function using the revised data for the periods 1949-73, 1949-75 and 1949-80 are shown in table 3.[4] There are three noteworthy revisions in the estimates. First, the coefficient on the relative price of energy and estimate of the output elasticity of energy are smaller in absolute value, though not in a statistically significant sense, with the new measures of output and capital. In the earlier estimation for 1949-73 and 1949-75, $\hat{\gamma}$ is 11.7 percent (t = 1.92) and 12.0 percent (t = 5.66), respectively. Second, the autocorrelation adjustment, $\hat{\rho}$, is smaller than before (0.63 for the 1949-75 period). Finally, the estimates for the period 1949-73 are even closer to those for the longer sample periods than they are with the earlier estimates. In the earlier estimations, there are no significant differences in the coefficient estimates across periods, but $\hat{r}$ is 1.2 percent per year and $\hat{\alpha}$ is 58.9 percent in the 1949-73 sample period; these are 1.6 percent and 64.9 percent, respectively, in the earlier estimation for the 1949-75 sample period.

An important hypothesis that was supported in earlier work is rejected using the revised data. A slowing in the time trend for technological change beginning in 1967 could not be rejected earlier. For all three sample periods in table 3, this hypothesis is rejected. A time-trend variable with a value of zero to 1966, then increased by one each year from 1966 on, was added to each equation estimated in table 3. The t-statistics for the slower trend variable are

Table 2
Indirect Least Squares Estimation of a Cobb-Douglas Production Function

Production Function: $X_t = A\, h_t^{\alpha}\, k_t^{\beta}\, E_t^{\gamma}\, e^{rt}$,

where
- X = output
- h = hours of all persons
- k = utilized capital stock
- E = energy input
- A = scale factor
- α, β, γ = output elasticity of hours, capital, and energy, respectively
- r = trend growth rate per year or per quarter
- t = time period

First-Order Condition for Energy: $Pe/P = \gamma X/E$,

where Pe/P = the price of energy relative to the price of output

Linear model: $$\ln X_t = \ln A + \frac{\alpha}{1-\gamma} \ln h_t + \frac{\beta}{1-\gamma} \ln k_t + rt - \frac{\gamma}{1-\gamma} \ln (Pe/P)_t$$

[4]The ordinary least squares (OLS) estimates of the coefficients in table 3 are virtually identical but the Durbin-Watson statistics are 1.28, 1.35, and 1.37 for the 1949-73, 1949-75, and 1949-80 periods, respectively. To check whether this autocorrelated error pattern results from the omission of significant lagged input effects on output, one and two period lags on the input variables are added to the equations in table 3 and their OLS counterparts. When this is done, the coefficients are not significant, the Durbin-Watson statistic does not change and the estimate of ρ shown in table 3 is not reduced.

Table 3
Production Function Estimate for the U.S. Private Business Sector

	1949-73	1949-75	1949-80
β_0	1.3440	1.4663	1.4971
	(3.78)	(10.70)	(13.25)
β_1	0.6885	0.7302	0.7201
	(12.53)	(13.25)	(13.07)
β_2	0.3115	0.2698	0.2799
	(5.67)	(4.90)	(5.08)
β_3	−0.0704	−0.0875	−0.0953
	(−1.00)	(−3.96)	(−6.22)
β_4	0.0168	0.0182	0.0177
	(7.84)	(9.69)	(9.48)
α	0.6432	0.6715	0.6574
	(9.57)	(14.30)	(14.58)
β	0.2910	0.2481	0.2555
	(5.27)	(4.64)	(5.31)
$\hat{\gamma}$	0.0658	0.0805	0.0870
	(1.07)	(3.96)	(6.81)
r	0.0157	0.0167	0.0162
	(6.11)	(10.24)	(10.36)
$\bar{R}^2$	0.97	0.97	0.97
SE	0.0091	0.0099	0.0102
DW	2.03	1.93	1.93
ρ	0.44	0.39	0.39

−1.67, −1.50, and −1.41, for the 1949-73, 1949-75, and 1949-80 periods, respectively. The slowing is not statistically significant at a 5 percent level in any of these periods.[5] In addition, a test for an optimal point for a trend break using a minimum standard error criterion fails to reveal a point superior to 1967. There is no evidence then for a slowdown in productivity growth due to disembodied factors influencing the trend.

The new estimates do not alter any of the other earlier conclusions. In particular, the status of a number of hypotheses tested earlier has been unchanged because of the changes in the private business sector concepts and the new measures. For example, tests of the Cobb-Douglas restriction yield the rejection of a translog specification of the production function.

[5]This result held before the recent revisions as well. See Rasche and Tatom, "Energy Price Shocks, Aggregate Supply," p. 25.

The output elasticity of hours during the three periods is not significantly different from the share of labor in total costs during each of the three periods. This is extremely important as the Cobb-Douglas production function implies a price elasticity for energy demand that may be biased upward. While this would not yield a bias in the estimated effect of energy prices on output, it would yield an upward-biased estimate of γ *and* a downward-biased estimate of α. There is no evidence of such a bias. The t-statistics for the equality of the $\hat{\alpha}$ estimate and the actual share of labor in each period are −0.22, 0.27, and −0.08, respectively, so that the hypothesis that $\hat{\alpha}$ is equal to the actual share of labor cannot be rejected.

Other factors that failed to add significantly to the productivity relationships estimated earlier continue to be insignificant. These include adjustments for pollution abatement capital and the changing proportions of young people (age 16-19) or women in the labor force.

Finally, it remains the case that pre-1974 production function estimates that omit energy developments break down after 1973. When the 1949-73 model is estimated without the relative price of energy, the standard error of the equation is identical to that shown in table 3. When the sample period is extended to 1975 and 1980, the standard error of the equation without energy rises to 1.24 percent and 1.37 percent, respectively. The Chow test indicates that a significant change in the structure of the production function occurs in each case when energy is omitted and the sample period is lengthened. As the stability of the standard errors in table 3 indicates, such structural changes can be rejected using the Chow test when energy prices are included.

An estimate of the production function using quarterly data from II/1948 to III/1981 is:

$$(2)\quad \ln X_t = \underset{(21.03)}{1.4688} + \underset{(23.81)}{0.7351}\ln h_t + \underset{(8.58)}{0.2649}\ln k_t - \underset{(-8.31)}{0.0893}\ln(Pe/P)_t + \underset{(16.94)}{0.0045}\,t$$

$$\bar{R}^2 = 0.99 \quad SE = 0.0074 \quad DW = 1.96 \quad \hat{\rho} = 0.76$$

$$\underset{(26.09)}{\hat{\alpha} = 0.6748} \quad \underset{(10.22)}{\hat{\beta} = 0.2432} \quad \underset{(9.05)}{\hat{\gamma} = 0.0820} \quad \underset{(18.41)}{\hat{r} = 0.0041}$$

The estimated coefficients are essentially the same as those in table 3. This quarterly production func-

tion is used below to derive the revised potential output series. The stability and all other properties discussed above for the annual equations in table 3 apply to the quarterly estimates as well.

The impact of a change in the relative price of energy on output, productivity, real wages, and the capital stock can be assessed using the production function estimate in equation 2. For a given employment of labor hours and capital services (the short-run effect), a 10 percent rise in the relative price of energy reduces PBS output (X_t) and productivity by 0.89 percent. The long-run elasticity of output, labor productivity, real wages, and the capital stock is $(-\gamma/\alpha)$, or 0.122 in this case.[6] Thus, a 10 percent rise in the relative price of energy leads to a long-run decline in output that is 36 percent larger than in the short run. In particular, a 10 percent increase reduces output, productivity and the capital-labor ratio by 1.22 percent. From the third quarter of 1973 to the third quarter of 1974, and, again from the first quarter of 1979 to the second quarter of 1980, the relative price of energy rose 40 percent.[7] Given the estimates above, each shock reduced productivity and potential output by 3.6 percent in the short run and 4.9 percent after adjustment of the market for capital goods.

REVISED MEASURES OF POTENTIAL OUTPUT

To determine potential real GNP, measures of potential employment of labor and capital are used to construct potential private business sector output. Other components of real GNP that are not sensitive to cyclical movements in output and are independent of the employment of labor are then added to obtain potential GNP. The latter components are the output originating in the rest of the world, general government, households and non-profit institutions.

The deviation of actual from potential employment of the nation's capital stock is based on an observation that at peak periods in the past, the Federal Reserve Board capacity utilization rate measure has been about 87.5 percent. This benchmark is used in the private business sector production function for full employment.[8]

The potential input of hours of all persons employed in the private business sector is found by determining potential hours per worker and potential employment. In each case, actual measures are related to a measure of slack in the labor market. This slack measure (UN) is the unemployment rate of the civilian labor force (U), minus the full-employment unemployment rate of the civilian labor force (UF), which was prepared in 1977 for the Council of Economic Advisers (UN = U − UF).[9] Hours per worker in the private business sector are found from the regression of hours per worker on excess unemployment in the current and past quarter, a shift variable (D) to account for the unusually high levels of hours per worker from III/1961 to II/1967, and a time trend (t) to account for a secular decline in hours per worker. For the period II/1948 to III/1981, this equation is:

$$(3)\quad \ln HPW = \underset{(546.1)}{0.797} - \underset{(-6.06)}{0.496}\, UN_t + \underset{(2.16)}{0.177}\, UN_{t-1} - \underset{(-57.06)}{0.001}\, t + \underset{(7.29)}{0.014}\, D$$

$$\bar{R}^2 = 0.99 \qquad SE = 0.0032 \qquad DW = 1.89 \qquad \hat{\rho} = 0.62$$

This equation has not been changed since 1977, except for the addition of the significant lagged slack

[6] See John A. Tatom, "Energy Prices and Capital Formation: 1972-77," this *Review* (May 1979), pp. 2-11, for an explanation and derivation of this result.

[7] Note that percentage changes are measured by the change in the logarithm of the relative price of energy. The exact magnitudes over the two periods are 40.7 percent and 40.3 percent, which measured as actual percentage increases are 50.2 and 49.6 percent, respectively. The relative price of energy rose another 12 percent in the first half of 1981 due to the immediate effects of domestic crude oil decontrol, but subsequent adjustments in the world market due to decontrol took 2.8 percentage points off this in the third quarter of 1981 alone.

[8] It can be argued that, at these peaks, "normal" operating conditions for the nation's plant and equipment are not observed and that, if demand were sustained, firms would increase investment to lower operating rates to optimal levels. In this case an 87.5 percent rate for the FRB capacity utilization rate overstates the "natural rate" of capacity utilization. This argument has been made in John A. Tatom, "The Meaning and Measurement of Potential Output: A Comment on the Perloff and Wachter Results," in Karl Brunner and Allan H. Meltzer, eds., *Three Aspects of Policymaking: Knowledge, Data and Institutions*, Carnegie-Rochester Conference on Public Policy, volume 10 (1979), pp. 165-78. The benchmark is supported by comparative movements in "excess" unemployment of the civilian labor force and the capacity utilization rate. When the capacity utilization is regressed on the excess unemployment rate described in the text below over the period I/1955-II/1981, the constant is 86.2 percent with a standard error of 0.78 percentage points when a significant lagged unemployment rate is included.

[9] This data series and its development is described by Peter K. Clark, "Potential Output in the United States 1948-80," *U.S. Productive Capacity: Estimating the Utilization Gap* (Washington University: Center for the Study of American Business, December 1977), pp. 21-66.

term.[10] The sum of the slack terms, −0.32, is virtually identical to the single contemporaneous term in the earlier estimates, so that only the timing of the cyclical effect has been changed. Potential hours per worker is found from the predicted values of equation 3 with the slack variable set at zero in the current and past quarter.

Potential employment in the private business sector is found in a similar manner. In particular, the logarithm of private business sector employment (ln EM_t) is regressed on a constant, a time trend (T), excess unemployment in the current and past quarter, and a trend shift variable (T2) to account for a shift in the trend rate of growth of the labor force after 1964. This particular break in trend was chosen on the basis of the lowest standard error of the equation. A break in trend is included to improve the efficiency of the estimation of the coefficients for the slack variables. The equation for the II/1948-III/1981 period is:

$$(4)\quad \ln EM = \underset{(371.63)}{3.94} + \underset{(7.21)}{0.002}\,T + \underset{(9.59)}{0.004}\,T2 - \underset{(-11.03)}{0.013}\,UN_t - \underset{(-2.63)}{0.003}\,UN_{t-1}$$

$$\bar{R}^2 = 0.91 \quad SE = 0.0046 \quad DW = 1.87 \quad \hat{\rho} = 0.92$$

When this equation is differenced, the autoregressive disturbances disappear (the Durbin-Watson statistic without first-order autocorrelation adjustment is 1.89), and the coefficients for the trend, break in trend, and slack variables are virtually identical. To find potential employment in the private business sector, the actual level of employment is cyclically adjusted by $(0.13\,UN_t + 0.003\,UN_{t-1})$ percent, according to the level and first-difference equations.[11]

This method of determining potential employment differs from the one this Bank used earlier. Until recently, potential PBS employment was found by subtracting the level of current employment outside the private business sector from potential civilian employment [$(1 - U_F)$ times the civilian labor force]. The former was equated to the difference in actual civilian employment and PBS employment. This method had two minor shortcomings. First, periodic census revisions and changes in sampling and estimation methods alter the civilian labor force and employment data, slightly affecting a measure such as the above and an accompanying measure of potential output. Second, this employment measure was somewhat cyclical, despite the absence of any permanent cyclical effects on the civilian labor force measure. The reason for this appears to be that PBS employment and civilian employment data are estimated by different methods, and their difference is cyclical.[12]

Revised quarterly estimates of potential real GNP are presented in the appendix to this article. These data as well as actual real GNP are shown in chart 2. The growth rate of this revised potential output series has been unchanged for past periods. The average growth rate of potential output was 3.7 percent from 1949 to 1973, the same as in the original estimates. This rate has varied somewhat in the past, however, largely reflecting differences in the growth rate of the labor force. For example, from 1951 to 1963, potential output grew at a 3.3 percent rate while the civilian labor force grew at only a 1.2 percent rate. Potential output growth accelerated to a 4.0 percent rate from 1963 to 1973, as labor force growth accelerated to a 2.1 percent rate.

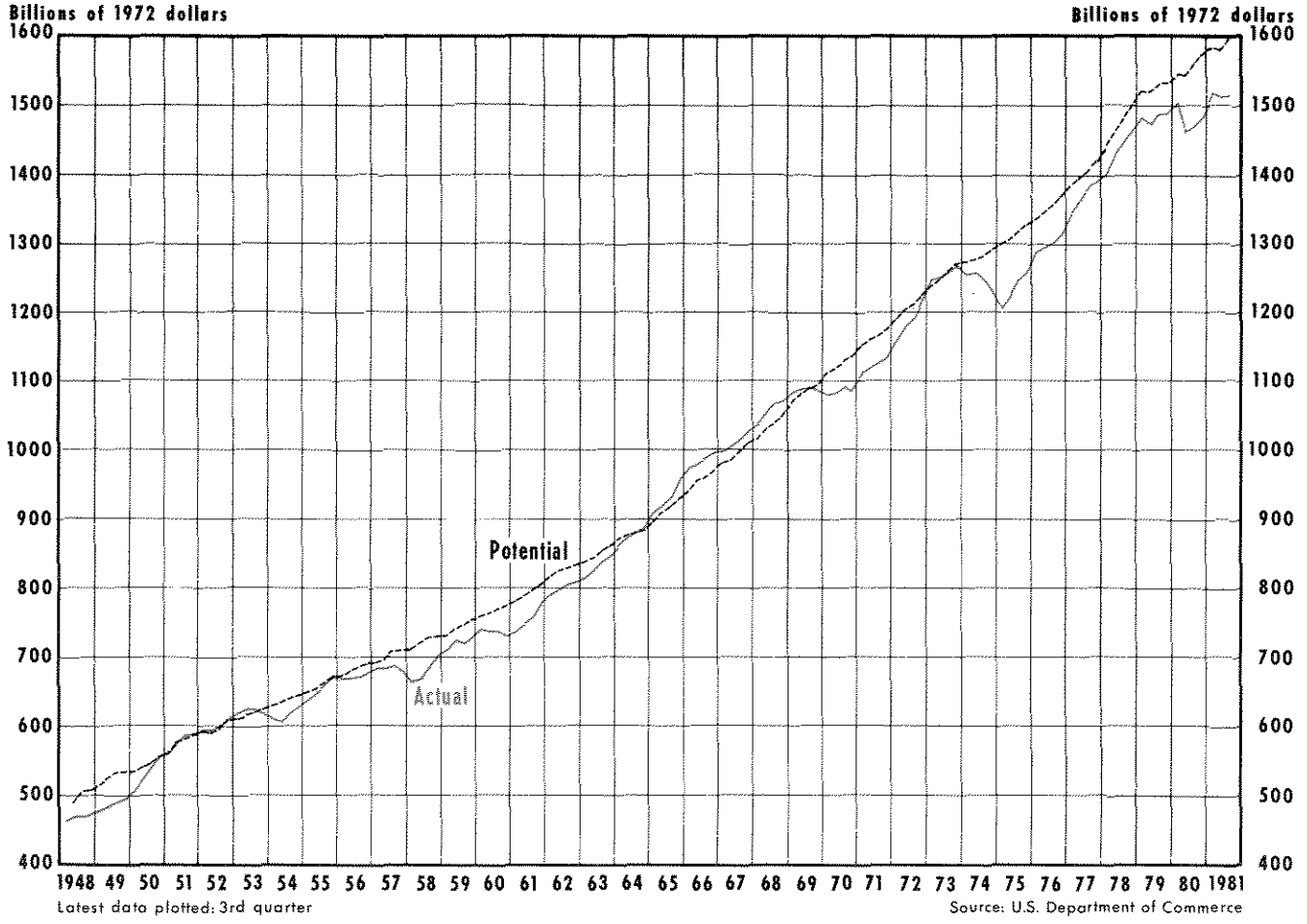
Since 1973, the potential growth rate has averaged 3.1 percent despite a labor force growth of 2.4 percent. The potential output growth rate has been as high as 5.0 percent in 1977-78. The annual growth rate of potential output in 1974 and 1980 was only 2.0 percent; in 1975, this growth rate was only 2.6 percent. These relatively slow rates reflect the impact

[10]This equation was explained in Robert H. Rasche and John A. Tatom, "Potential Output and Its Growth Rate — the Dominance of Higher Energy Cost in the 1970's," *U.S. Productive Capacity: Estimating the Utilization Gap* (Washington University: Center for the Study of American Business, December 1977), pp. 76-77. The unusual shift in hours per worker in the '60s has also been noted by George L. Perry, "Potential Output and Productivity," *Brookings Papers on Economic Activity* (1:1977), pp. 11-47. Tests of additional lagged values of the excess unemployment rate found them to be insignificant.

[11]The effect of a one percent rise in the excess unemployment rate on PBS employment should be roughly a percent decline equal to the ratio of the civilian labor force to PBS unemployment. This may be derived from the relation that PBS employment is (1 — U) LF — NE, where U is the unemployment rate of the civilian labor force (LF), and NE is non-PBS employment, measured by the difference in civilian employment and PBS employment. The actual ratio of the labor force to PBS employment in the sample period has a mean of 1.26. The remainder is due to cyclical variation in non-PBS employment that does not affect non-PBS output.

[12]The difference between establisment-based payroll measures of employment and households-sampling-based civilian employment measures is procyclical so that the old method resulted in a measure of potential PBS employment that was inversely related to excess unemployment. This cyclical difference is discussed by Alexander Korns, "Cyclical Fluctuations in the Difference Between Payroll and Household Measures of Employment," *Survey of Current Business* (May 1979), pp. 14-44.

Chart 2
Real GNP



of sharp increases in the relative price of energy resources.

Table 4 shows the annual averages of recent levels of potential GNP together with recent estimates by the Council of Economic Advisers (CEA).[13] The CEA estimates range from 1.4 percent below to 1.0 percent above those presented here. The percentage difference between the two measures is virtually the same in 1973 as reported earlier, but the 1977 CEA estimates for the period 1974-76 rose from 1.1 percent larger to almost 3 percent larger than this Bank's estimates. The two estimates are now extremely close, largely due to major revisions in the CEA estimates reported in the *Economic Report of the President* in 1977 and 1978. These revisions pushed the 1973 level below that estimated by this Bank, but then assumed a roughly constant growth rate that was faster in 1974-76, then slower in 1976-79, than that estimated here. The CEA reported in 1981 that potential output was expected to grow at a 2.9 percent rate in 1979 and 1980, then return to a 3.0 percent rate.[14]

[13]See Council of Economic Advisers, *Economic Report of the President*, 1981.

[14]The CEA estimate is apparently based upon the expectation that the labor force will grow at a 1.75 percent rate, hours per worker will decline at a secular rate of 0.5 percent and that potential productivity (output per hour) will rise at about a 1.75 percent rate. See *Economic Report*, 1980, pp. 89-90 and *Economic Report*, 1981, pp. 180-81. Such a rate of productivity advance may appear optimistic in light of the experience since 1978 or in 1973-75. It should be noted, however, that potential

Table 4
Recent Measures of Potential GNP (billions of 1972 dollars)

	Potential GNP	CEA estimate	Ratio
1973	$1,254.8	$1,234.9	98.3%
1974	1,279.7	1,277.5	99.8
1975	1,313.0	1,320.6	100.6
1976	1,351.8	1,365.1	101.0
1977	1,400.6	1,411.4	100.8
1978	1,470.0	1,459.3	99.3
1979	1,526.2	1,504.6	98.6
1980	1,556.2	1,548.5	99.5

The primary difference shown in table 4 is that the CEA growth rate of potential output of 3.4 percent in 1973-76 exceeds the 2.5 percent rate estimated here, while its growth rate for 1976-79 of 3.3 percent is less than the 4.1 percent rate estimated here. It appears that, in recent years, the CEA has smoothed its potential output series to capture the sharp supply shock effects on potential output by lowering the growth rate of potential output over several years. As a result, the levels of potential output have not differed substantially. This difference is to an extent intentional, as the CEA has always employed a given growth rate for long periods. This tendency has been tempered in recent years, as can be seen by the slight variability in the CEA annual growth rate shown in table 4. It may be that the 1980-81 productivity losses that result from energy shocks will be largely reflected in the CEA's use of too slow a rate of potential growth for the early 1980s.

RECENT ACTUAL AND POTENTIAL PRODUCTIVITY DEVELOPMENTS

The sharp drops in potential output growth in 1974-75 and 1980 reflect the effect of major energy price changes on actual and potential productivity.

output per hour, discussed in the next section, rose over five-year periods at no less than a 2.5 percent rate from 1948-73. Following the implementation of accelerated depreciation and corporate tax cuts, the pace of capital formation rose sharply so that it surged to the post-World War II peak rate of 3.2 percent from 1963 to mid-1970. Even during 1978 potential productivity growth had risen to over a 2 percent rate as the adjustment to the prior energy shock was apparently approaching completion. A repeat of that pattern and recent supply-side policies suggest a more rapid pace of productivity growth from 1982-85 than that projected by the CEA.

Table 5
Recent Productivity Developments (compound annual rates)

	IV/1948-IV/1973	IV/1973-IV/1980	Difference
Growth of output/hour	2.87%	0.67%	2.20
Potential growth rate	2.82	0.94	1.88
Cyclical factors	0.09	−0.20	0.29
Residual factors	−0.04	−0.07	0.03
Contribution to potential growth rate of:			
Capital accumulation	0.92	0.28	0.64
(Growth in high-employment capital-labor ratio)	(3.52)	(1.04)	(2.48)
Energy price changes	0.07	−1.13	1.20

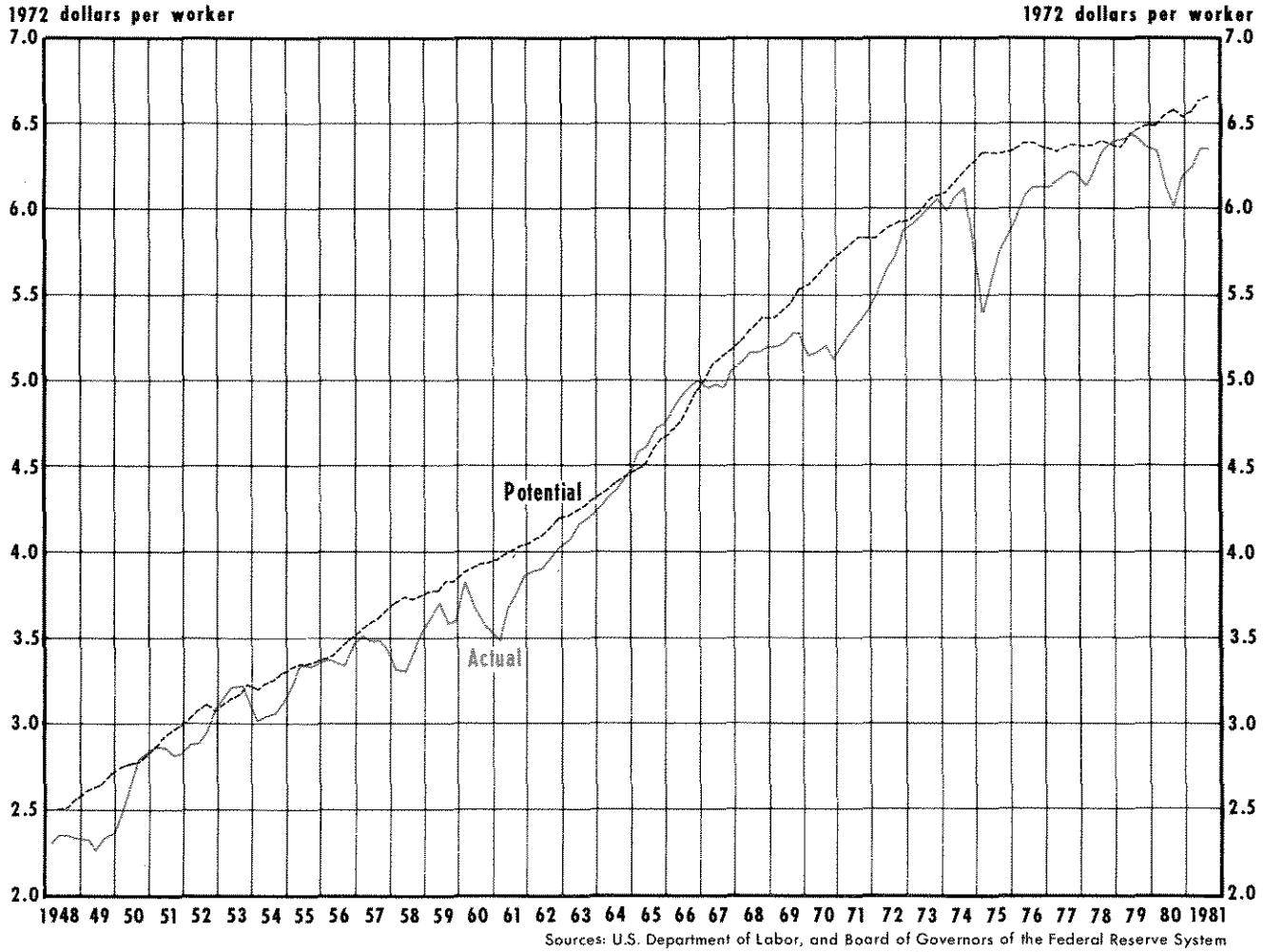
Since 1973, productivity's abysmal performance has been a major concern for policymakers. Thus, it is useful to detail the factors influencing such growth over the last seven years.[15]

An analysis of the actual and potential productivity decline for the private business sector appears in table 5, where growth rates and the contribution of various factors are compared for two periods: 1948 to the end of 1973, and 1973 to the end of 1980. Output per hour grew at a 2.87 percent rate from IV/1948 to IV/1973, then slowed to a 0.67 percent rate over the next seven years. This growth can be analyzed in two ways. The first is to look at the contribution of the factors entering equation 2: the actual changes in the growth of employed capital relative to labor, the relative price of energy, the pace of technological change, and residuals due to random errors of fitting the equation at the end points of the period. The second, shown in the top panel of table 5, is to break down actual productivity growth in each period into changes due to the growth of potential productivity, changes due to cyclical variations in the employment of capital and labor at the beginning and end periods, and differences in the residual or random error component of equation 2.

[15]In contrast to Edward F. Denison, "Explanations of Declining Productivity Growth," *Survey of Current Business*, (August 1979, part 2), pp. 1-24, the analysis here of post-1973 productivity developments fully explains the productivity "puzzle," while other explanations do not. See Tatom, "The Productivity Problem" or especially Denison's paper for a discussion of these other factors. The puzzle is presumably all the more challenging to other analysts due to the post-1978 cessation of productivity growth.

Chart 3

Capital Labor Ratio (Private Business Sector)



Sources: U.S. Department of Labor, and Board of Governors of the Federal Reserve System

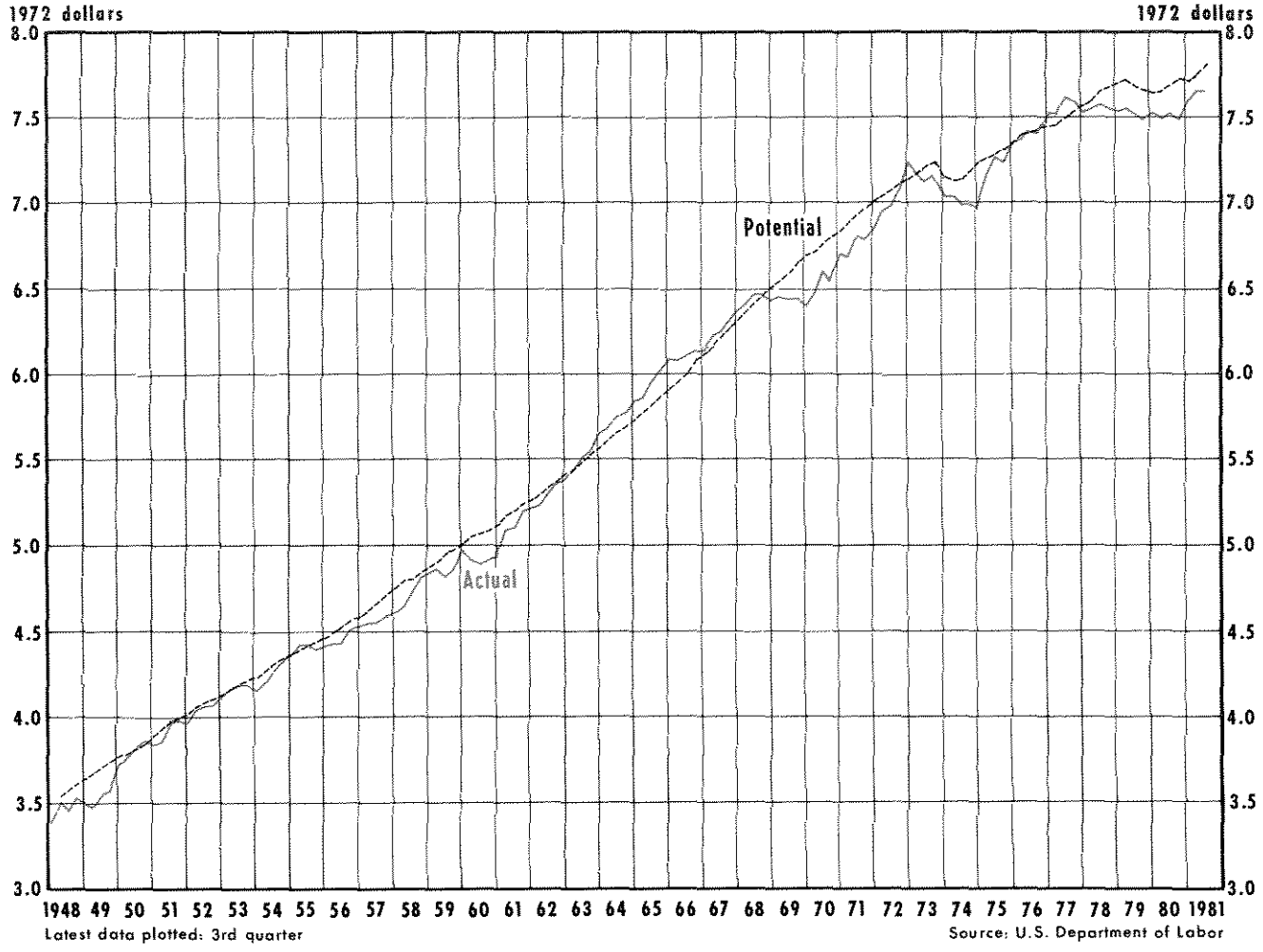
The potential ratio is the capital stock adjusted for an 87.5% capacity utilization rate divided by potential hours of employment in the private business sector. The actual ratio uses the actual capacity utilization rate and hours of employment in the private business sector.
Latest data plotted: 3rd quarter

The contribution of cyclical factors accounts for the difference between the productivity effect of the growth of the potential PBS capital-labor ratio (the contribution of the capital-labor ratio to potential growth) and the effect of the actual growth in the utilization of capital per hour. The discrepancy between the two arises from the cyclical variability of the capital-labor ratio shown in chart 3. The sum of the "cyclical factor" and the contribution of "capital accumulation" to potential productivity growth indicates the estimate of the actual impact of movements in the observed ratio of utilized capital to labor hours on the observed productivity growth.

Most of the 2.2 percentage-point decline in productivity growth over the last seven years has been due to factors that slowed potential productivity growth. For the particular comparison shown, cyclical differences between productivity movements in the two periods or residual errors account for only 0.3 percentage points of the observed slowing.

In the lower part of the table, the factors contributing to the potential productivity growth slowdown are shown. What is omitted in the lower part of the table is the trend growth of total factor productivity which contributed 1.82 percentage points to the rate

Chart 4
Potential and Actual Output per Hour (Private Business Sector)

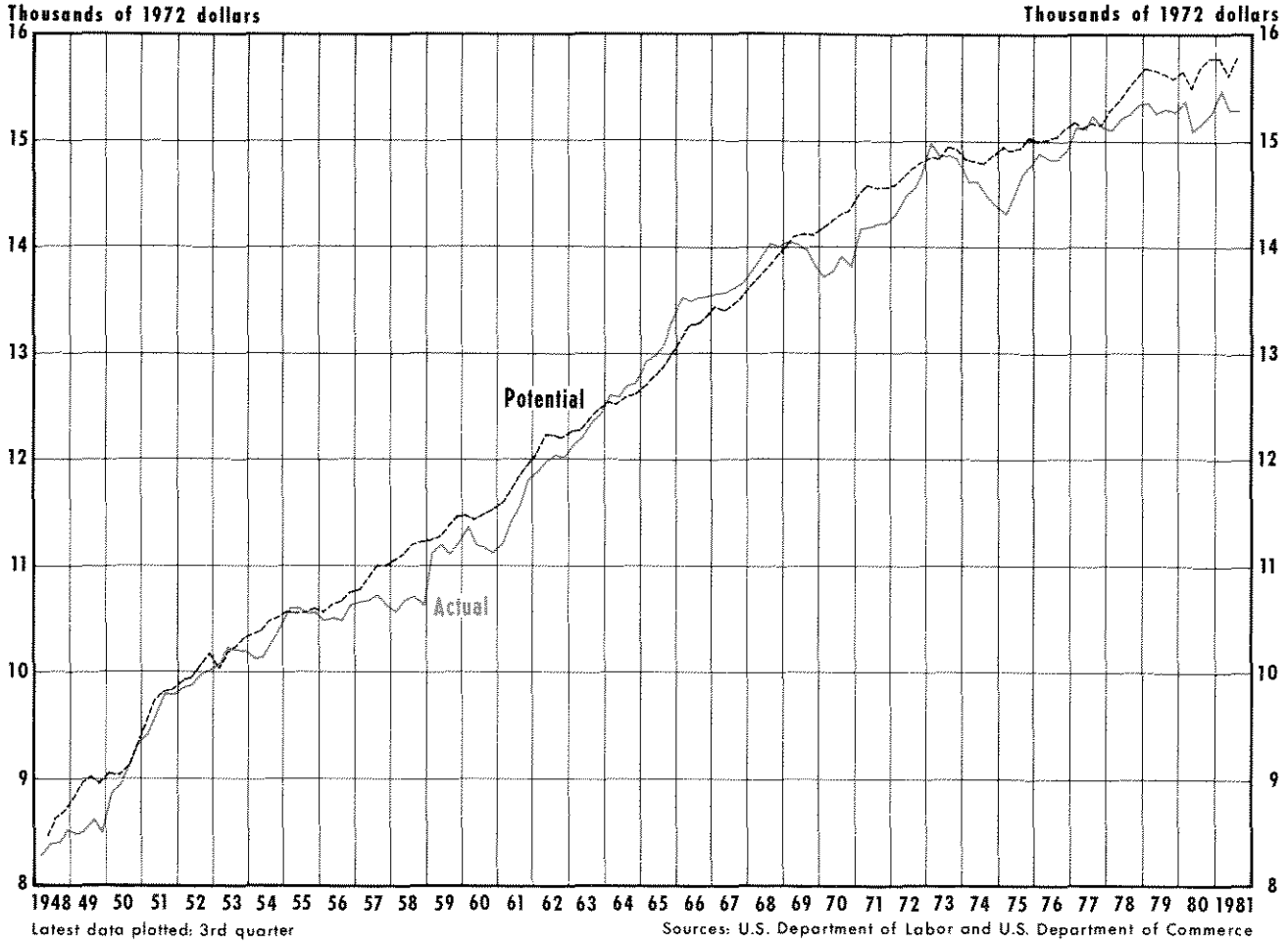


of productivity growth in both periods. The direct effect of energy price shocks over the last seven years has been to reverse the slight positive contribution of energy price declines over the prior 25 years, so that 1.20 percentage points of the 1.88 percentage-point-per-year decline in potential productivity growth has been due to this factor. The remainder has been due to a slowing in capital formation.

As noted in parentheses, the growth rate of the capital stock relative to potential hours of employment was 3.52 percent over the 25 years ending in 1973; subsequently, this growth slowed to about one percent. This slowing reduced the contribution of capital formation from a 0.92 percent rate to a 0.28 percent rate over the last seven years. When this result is combined with the effect on productivity growth of cyclical movements in the capital-labor ratio, the result is that capital formation, which added 1.01 percentage points (0.92 + 0.09) to the actual pace of productivity growth from the end of 1948 to the end of 1973, only contributed 0.08 percentage points to the actual rate of productivity growth from the end of 1973 to the end of 1980. Implicitly, cyclical differences between the end of 1973 and 1980 offset the effect of growth in capital per hour, so there was virtually no change in the actual employment ratio.

The small changes in table 4 become quite large when compounded over the seven-year period. For example, the slowing in the potential growth rate over the seven-year period reduces private sector

Chart 5
Real GNP per Civilian Worker



output by 13.8 percent by the end of 1980. The direct impact of energy price increases alone over these seven years reduces output by 8.3 percent.

Moreover, a large share of the reduction in capital formation since 1973 has been due to energy price developments. The inclusion of the energy price-induced slowing in the desired capital-labor ratio leads to an 11.5 percent loss in output. The remaining loss in potential productivity is associated with a non-energy-related slowing in capital formation.[16]

Finally, it should be noted that table 5 presents a summary view of the effect of energy price changes on actual and potential productivity that does not reflect the actual pattern of events. In particular, the "slowdown" described in table 5 is not continuous. Associated with each energy shock is a once-and-for-all decline in both measures of productivity, with

[16]Factors responsible for the cessation of growth in the utilized capital-labor ratio besides the decline in the productivity of capital due to energy price changes and minor cyclical influences, include such factors as higher expected inflation, inflation uncertainty, and riskier returns due to an increased probability of governmental intervention through regulatory initiatives. See Tatom, "The Productivity Problem." Patric H. Hendershott, "The Decline in Aggregate Share Values, Taxation, Valuation Errors, Risk, and Profitability," *American Economic Review* (December 1981), pp. 909-22, discusses these and other factors that contribute to the slowdown in capital formation and argues that inflation alone has had little impact on the decline in share values and, implicitly, capital formation. Instead he claims that a change in risk premiums (attributed to increased uncertainty about price and regulatory changes) in equity and bond yields and reduced pretax profitability have been the reason for about half the decline in share values. Hendershott does not assess the role of a higher relative price of energy in reducing the pretax real profitability of the corporate capital stock.

temporarily slower growth as the capital-labor ratio is adjusted toward a lower desired level. This pattern is more clearly apparent in chart 4, which shows potential and actual measures of private business sector output per hour. Deviations in the two are predominantly due to the business cycle. The pattern of potential productivity developments in chart 4 shows virtually no growth from mid-1973 to mid-1975 and relatively slow expansion from mid-1975 to mid-1977. Following the second energy shock, potential productivity fell, then was virtually unchanged until the end of 1980. The second phase of a relatively slow pace of potential productivity expansion is apparent in the first three quarters of 1981.

Chart 5 shows an alternative measure of productivity, real GNP per civilian worker, again measured on both an actual and a high-employment basis.[17] The primary difference from chart 4 is the secular rate of decline in hours per worker. Both actual and potential real GNP per worker have flattened out twice relative to the prior trend growth, with a resumption of growth from early 1977 until early 1979. At the end of 1980, potential real GNP per worker stood only 5.7 percent higher than at the end of 1973, so that five years worth of the prior trend growth (2.2 percent rate) has been lost during the past seven-year period.

SUMMARY

Recent revisions in the measures of the nation's output and capital stock, as well as minor changes in procedures, have altered this Bank's measures of potential output. The major conclusions of earlier Bank studies, however, have been unaffected by these changes. In particular, the growth of potential output has been sharply reduced by the 1973-74 and 1979-80 energy shocks and subsequent adjustments in the desired capital intensity of production. These effects have been confirmed by the re-estimation of earlier production function coefficients, and, more important, the confirmation of the prior empirical estimates in the latest round of energy price increases.

The decline in the growth of potential output since 1973 has, in recent years, been acknowledged by the Council of Economic Advisers, but through a trend reduction rather than through sharp temporary declines in 1974-75 and 1979-80 as implied here. Nonetheless, the level of potential output estimated by the CEA in recent years is little different from this Bank's estimate. The slowing in potential output masks a sharper reduction in the growth of productivity in recent years. A detailed analysis of productivity developments shows a marked deterioration in growth relative to past trends. In the measurement of potential output, this deterioration has been partially offset by a more rapid growth of both potential and actual employment.

[17]The high-employment measure of civilian employment is found by regressing changes in the logarithm of the civilian labor force on a constant, a shift for faster labor force growth after 1964 and current and one-lagged changes in the excess unemployment rate. Additional lags are not statistically significant. Moreover, the constraint that the effect of slack is zero after two quarters could not be rejected. The effect of a one percentage-point increase in slack is to increase the labor force by 0.2 percent ($t = 2.34$) in the current quarter and this is offset in the subsequent quarter. To find the high-employment civilian employment, these cyclical effects are added back to the observed civilian labor force and high-employment unemployment (UF) (LF) is removed.

(See appendix on next page)

Appendix

Potential GNP (in billions of dollars)[1]

	I	II	III	IV
1948	NA	$ 489.1	$ 502.9	$ 506.1
1949	$ 515.0	523.6	530.1	532.0
1950	536.1	540.7	546.9	555.7
1951	566.3	576.6	582.9	586.7
1952	592.3	591.4	599.3	609.3
1953	612.8	615.6	617.5	621.6
1954	630.1	634.3	641.0	643.7
1955	648.6	653.5	662.9	672.4
1956	672.3	679.7	683.5	687.8
1957	691.2	698.0	707.7	708.5
1958	710.1	720.8	730.4	731.3
1959	732.0	739.8	746.3	756.0
1960	757.7	763.6	768.4	774.5
1961	782.8	789.2	797.7	806.1
1962	813.7	824.7	828.8	828.9
1963	836.9	843.5	853.7	862.7
1964	870.9	877.1	881.2	884.7
1965	895.9	908.5	918.6	930.7
1966	942.8	955.6	963.2	973.1
1967	981.4	985.3	997.9	1,010.2
1968	1,017.1	1,033.1	1,041.4	1,051.3
1969	1,069.3	1,081.3	1,092.0	1,097.3
1970	1,109.9	1,117.8	1,128.6	1,136.6
1971	1,150.2	1,160.8	1,166.4	1,176.3
1972	1,188.9	1,203.1	1,216.8	1,226.2
1973	1,236.9	1,247.6	1,262.3	1,272.4
1974	1,273.5	1,275.0	1,280.1	1,290.3
1975	1,300.3	1,307.3	1,316.8	1,327.5
1976	1,335.3	1,345.7	1,355.6	1,370.5
1977	1,384.8	1,394.5	1,405.5	1,417.7
1978	1,437.8	1,460.7	1,479.5	1,502.2
1979	1,521.7	1,520.9	1,529.3	1,533.1
1980	1,545.6	1,544.4	1,560.9	1,573.9
1981	1,584.0	1,580.4	1,595.0	

[1]Prepared using data available through November 30, 1981.